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Innovating in Education
Effectiveness of PBL on students' skills

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Abstract

"Do not train a child to learn by force or harshness; but direct them to it by what amuses their minds, so that you may be better able to discover with accuracy the peculiar bent of the genius of each."

Plato (427—347 B.C.E)

The purpose of this study was to assess the impact of project-based learning on students' motivation and critical thinking, considering the importance of preparing students for a knowledge-based economy. The research analysed 113 students from four schools were the project *Mentes Empreendoras* was implemented. Pre and post-test analyses and a matching procedure were conducted to guarantee comparability. The study suggests positive evidences of project-based learning in the motivation and critical thinking skills of students, indicating that an educational approach that fosters self-discovery might be well suited to engage and motivate students and promote their critical thinking.

Keywords: Education, Project-based learning (PBL); 21st century skills; Motivation; Critical Thinking; Mentes Empreendedoras (ME);

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1. Introduction

Project-based learning has long been a controversial topic when addressing educational policies. The fact is that in a rapidly changing society, where information flows fast and unfiltered, both governments, professors and parents are struggling to find educational programs which might be able to shape better qualified and happier citizens in the future. It is in the midst of this challenging background, that project-based learning appears, in the hopes that different approaches might be better suited to tackle current challenges in education. Nonetheless, there is still a lack of research trying to understand what can be project-based learning impact in the attainment of technical skills, but also crucial social skills. This gap on research is particularly large in the Portuguese context.

Therefore, the present study's main goal is twofold. The experiment conducted in this study will try to uncover the impact of the implementation of a project-based learning approach in specific schools around Lisbon. Moreover, it will also try to address the main challenges of this kind of educational approach, and provide recommendations for further research and analysis. Therefore, the main goal of the study is to understand the possible impact of the PBL methodology implemented by the social organization *Mentes Empreendedoras,* in students' acquisition of crucial 21st century skills. To do so, the following hypothesis were tested:

H1: *The project-based learning approach implemented by Mentes Empreendedoras has a positive impact in the* ***critical thinking skills*** *of students who experience the project.*

H2: *The project-based learning approach implemented by Mentes Empreendedoras has a positive impact in the* ***motivation towards projects*** *of students who experience the project*.

The paper starts by introducing the main theoretical concepts and history of project-based learning, as well as the main theoretical findings on the impact in different variables of student performance.

It then presents a small summary of *Mentes Empreendedoras*, before moving into the methodology, comprising the description of both outcome and control variables, as well as the presentation of the model used and the method to assess the results. Finally, the main results are presented, as well as a discussion on the findings, before arriving to the conclusions and suggestions for further research.

2. Literature Review

Inquiry-based learning is a set of educational approaches considered crucial to foster deeper learning experiences, problem-solving and critical-thinking, by connecting knowledge acquisition with its application (Barron and Darling-Hammond 2010). In fact, the idea of using inquiry as an educational tool comes from far back in History. Since Ancient Greece Socrates' questioning method, to the Renaissance and the discovery of the scientific process, up until the beginning of the 20th century, with William Kilpatrick in 1918 and John Dewey in 1938. Throughout history is easy to find multiple philosophers and scholars advocating for the use of inquiry and projects as a way for students to gather and retain knowledge (Friesen and Scott 2013). Although the debate on its relevance is not new, inquiry-based learning has gained a new momentum since the early 1970s and 1980s with the rise of constructivist theories in the educational field.

Constructivists claim that students do not simply learn by being told but learn by doing and contextualizing knowledge into meaningful and authentic learning experiences (Boaler 2001). Therefore, recent discussions in education have been focused on the question of whether our classrooms are truly preparing students for the challenges of a knowledge-based economy. It is in the midst of this debate, that Project-based learning (hereinafter PBL), an inquiry-based approach, has gained followers and users in schools all over the world.

PBL is defined as a student-centered, inquiry-based learning approach, where students develop projects as a way to acquire knowledge on a defined range of topics. As described by John Thomas

(2000) there are 5 criteria to PBL: projects have to be central to the curriculum, have to be focused on questions/problems that drive students to deal with the central concepts of a discipline, have to involve students in a constructive investigation, have to be student-driven to a significant degree and lastly, projects have to be realistic and authentic. (Thomas 2000). Through PBL students are able to immerse themselves in the learning experience, which raises their personal involvement, promotes cooperative work, allows students to make connections between problems and solutions and also incentivizes greater autonomy, greater responsibility and acquisition of complex skills. (Rebelo and Gomes 2014)

The result of the recent debate on PBL is an extensive body of research on the definitions, outcomes and effectiveness of this learning approach. Studies have tried to grasp the possible effectiveness on different student outcomes that can be divided into three main categories: knowledge acquisition and academic achievement; reasoning and knowledge application and finally, social and behavioral skills (Hoidn and Kärkkäinen 2014).[1] Moreover, a review of the literature on the effectiveness of PBL from prekindergarten until the 12th grade, defined seven possible student outcomes: academic outcomes, developmental gains, student perceptions about project-based versus traditional learning, attitudes towards a subject course, group process, perceptions of peers, and perceptions of efficacy/ability (Holm 2011). One of the most quoted studies on PBL is the one where Boaler (1998) executed a 3-year case study, comparing mathematics learning in a school of PBL with a traditional school. Her longitudinal study in England, compared 300 students who were matched at the beginning of the study by gender, ethnicity, social class and prior attainment. The students had also followed the same mathematics teaching approach in the 2 years prior to entering into

[1] The study by Hoidn and Kärkkäinen (2014) analysis the main outcomes of problem-based learning, which is a very simmiolar learning approach to project-based learning, and is also part of the inquiry-based approaches to learning. Hence, and for simplification purposes, the present study draws from the categorized outcomes for problem-based learning defined in the study of Hoidn and Kärkkäinen.

different schools. Her findings showed that this educational approach promotes deeper and meaningful learning, which indicates a longer retention of knowledge. The study also found supporting evidences of increase in students' motivation. Shepherd (1998) compared 5th and 6th grade students who were under a nine-week problem-based learning project called Probe Method. The study used pre/post-tests to assess the critical thinking skills of students, and a non-equivalent group design study was conducted. Shepherd demonstrated that there was a substantial increase in the critical mindset of the children taught under the inquiry-based learning approach. Furthermore, Geier et al (2008) produced a longitudinal experiment to analyse the reform efforts on the district of Detroit between 1998 and 2001, where PBL classrooms were implemented. They compared the 3 years test score results of students who participated in the schools chosen to implement the PBL project, with the rest of the students in the district. Their findings showed increase in the standardized state tests in science scores of students under PBL. Gültekin (2005) also conducted a study to assess the effectiveness of a Turkish primary school reform that implemented PBL in classrooms. The author compared two 5th grade classes of the same school (a total of 40 students) where one was the experimental group and the other the control group. The two classes were balanced according with student characteristics and test scores. It demonstrated not only an increase in academic achievement of students, but also an increase in motivation and in finding school a meaningful and enjoyable experience. Besides the above mentioned studies, there is still a large body of research that accounts for the success of PBL both in terms of knowledge acquisition and application, but also in terms of students' social skills, including attitudes towards learning, collaborative work, communication, creativity, critical thinking and problem-solving (Kaldi et al. 2011; Penuel, Means and Simkins 2000; Horan, Lavaroni and Beldon 1996; Ozdemir 2006; Özdener & Özçoban 2004). Most of the studies above mentioned used both quantitative and qualitative tools to conduct their experiments and gather results. The control vs experimental group

is the most common research design, and there is little literature on the use of randomization to assess the results of PBL. The study by Boaler and Gultekin both tried to ensure greater balance between the two student groups in analysis, ensuring a decrease in the sources of bias. Particularly, Boaler accounted for key unobservable factors in student performance – such as socioeconomic status and prior achievement, decreasing the potential bias of the study's results.

Despite the fact that the vast majority of academic publications seem to favor PBL as a valid educational approach, there are still some controversy revolving around the possible effectiveness and challenges to implementation. Mayer (2004) and McCray DeHann and Schunk (2003) both suggest that guided instruction favours and facilitates learning more than discovery and inquiry-based learning. Particularly, Mayer (2004) claims that guided instruction can in fact be more successful in promoting active learning – learning where students are involved and cognitively engaged. For Mayer, too much freedom might mean that students fail to come into contact with the necessary content and learning material. (Mayer 2004) Moreover, Kirschner, Sweller & Clarck (2006), Petrosino (2008) and Blumenfeld, et al. (1998) argued that self-directed learning might give too much discretion to inexperienced students. This might generate situations where the opportunity for connecting learning with the project execution is lost, compromising the learning goals of a specific subject. Hence, teacher involvement and guidance, seem to be needed and crucial conditions for optimal learning under a PBL approach (Holm 2011). Moreover, it is also considered the need to in both theory and content application to ensure that learning occurs. (Kirschner and Clark 2006)

Furthermore, the literature presents a number of challenges to the implementation of PBL, which can compromise the success of this learning approach. In his comprehensive literature review, Thomas (2000) describes challenges associated with students, teachers and schools when trying to implement a PBL approach. These difficulties include students' challenge to conduct a systematic

inquiry, sustaining motivation, participate in a disengaged manner or even the lack of background necessary to make sense of the inquiry of PBL. This approach is also challenging for teachers, who tend to report conflicts and dilemmas when enacting PBL, due to deep-rooted and entrenched beliefs on how learning should occur inside a classroom. Moreover, school factors such as lack of resources, inadequate technology or even non flexible schedules might affect the successful implementation of a PBL approach.

All in all, compared to other educational approaches, PBL seems to not only foster the understanding and learning of content, but also tends to promote a deeper understanding and retention of the knowledge acquired in classrooms, since is fosters practice and contextualization of the subjects learnt. There is also vast evidence that PBL is an effective method to teach complex processes and foster creativity, communication, problem-solving and decision making (Hoidn & Kärkkäinen 2014; Thomas 2000). Moreover, when executed properly, it seems to have the capacity to promote engagement and motivation in students, which in turn tends to increase their involvement and attendance (Baş 2011).

Notwithstanding the significant body of research on PBL, it is important to keep in mind the existent gap in the literature, namely on the understanding of the role that this type of approach might have in fostering innovation and the so called 21st century skills (Hoidn and Kärkkäinen 2014) – *problem-solving, collaborative work, communication, critical thinking*. Most studies are mainly focused on grasping the effectiveness of PBL in terms of academic achievement, and some reported benefits in terms of social skills. However, since the challenges that students will face in the current globalized and knowledge-based economy are different, the skills they acquire and retain in school should also address those challenges (Soland, Hamilton, and Stecher 2013; Partnership For 21 St Century Skills 2009). Moreover, it is also important to note that there is little evidence of literature on PBL implemented in the context of the Portuguese educational system.

2.1 Mentes Empreendoras

Mentes Empreendedoras (hereinafter ME) is a non-profit organization founded in 2010 with the goal of fostering leadership, entrepreneurship, talent and autonomy in Portuguese secondary school students. Initially, the ME cycle– a process where students are inspired and supported by a fellow and teacher to develop their own projects in their communities (see Appendix II for the model) – was implemented in 9 schools in the *Area de Projecto*[2] course. One year after the implementation of the pilot, the Portuguese Ministry of Education extinguished *Area the Projecto* from the curriculum. From this period onwards ME worked as an extra-curriculum activity, except for one or two cases where a teacher suggests to use the methodology to teach their course. Since 2010 the project has been implemented in over 30 schools, involving 682 students, in a total of 97 projects developed.

Although ME is not formally included in a discipline, the main goal of the associations' intervention model is to help students to understand crucial 21st century skills such as problem-solving, responsibility, critical thinking, autonomy, leadership and communication, through the development and implementation of an authentic project. To do so, ME uses the methodology of PBL, as defined in the present study and according to Thomas' (2000).

Mentes Empreendedoras' methodology consists of a sequence of 7 workshops, one per month in each school, where the same fellow presents the ME's methodology and guides the development of the projects by the students. Besides the workshops, ME also uses online platforms for communication and to monitor the participation and commitment of the participants. Through this approach, students are motivated to develop projects which impact their communities.

[2] *Area de Projecto* was a course lectured in the 12th grade in Portugal, where students were encouraged to develop a one year project in small groups. The aim was to develop leadership, problem-solving and responsibility in students.

3. Methodology

The present study proposes a model to assess learning outcomes, based on a quasi-experimental approach, where both qualitative and quantitative data will be analyzed.

3.1 Impact Model

To assess the impact of the PBL approach, a framework composed of quantitative instruments (questionnaires) was implemented in 4 schools near Lisbon where ME is already implementing its project. The qualitative analysis of the study will be based on the testimonies of the professors in charge in each school and also students in the program, to try to grasp their perception on PBL and on ME's impact.

The tests were applied in person, and lasted a total of 60 minutes for each group of students. There were two main stages of application: the first one (pre-tests) in November and December, before the ME's workshops started in schools. The second stage (post-test) happened in February, after ME's implementation of 4 workshops in each school. On these workshops students were challenged to create a small project and learnt several skills related with motivation, responsibility, autonomy, collaborative work, critical thinking and on how to develop and execute a project. The main tests were the same, however, there were some slight changes in the order of questions and subject of the critical thinking test, to try to minimize the effect of the two stage tests on the study's internal validity (Shadish, Cook, and Campbell 2002). It was also a way to guarantee a more willing collaboration of students. Two tests were applied (see Appendix III for the questionnaire and Appendix IV for the *Direção Geral da Educação*'s authorization):

The Ennis-Weir Critical Thinking Essay Test: The Ennis-Weir is an essay test of critical thinking skills that takes the form of a letter to the editor of a fictional newspaper. It has both instructional and research purposes, meaning it can be used to teach critical thinking skills, but also as a basis

for comparing groups as in case of the present study. It targets mainly high school and college students. However, the authors who developed the test have applied it to students in junior high-school with success (6^{th}, 7^{th} grade) (Ennis and Weir 1985). The test has a proven reliability and validity (Ennis and Weir 1985) and measures different aspects of critical thinking. (Oliveira 1992). The reason the test was chosen, comes from the fact that this is one of the only essay tests to measure critical thinking which allows to remove as much as possible the artificiality, and create a realistic context for critical thought and argument. An adaptation of the original test was used in the present study (the translation, and the change in subject on the post-test).

Intrinsic Motivation Inventory (IMI) by Ryan, Koestner, & Deci (1991): This attitude scale, allows the measurement of participants' experience in different activities and their motivation towards those experiences. In the context of the present study the IMI scale measured students' experience with project work and mostly their motivation in these initiatives. The scale measures 5 critical points: Interest/Pleasure; Understood Choice; Understood Skill; Pressure/Tension; Value/Utility.

3.2 Outcome Variables

To assess the effectiveness of PBL the present study analyzed the acquisition and retention of critical 21^{st} century skills. Many of these skills are highly attractive for employers, such as communication, critical thinking and motivation (White 1997). Therefore, the outcome variables in analyses are the following:

Critical thinking and problem-solving skills: Critical thinking can be defined as the ability to make correct analyses, inferences and evaluations, (Soland, Hamilton, and Stecher 2013) or as Ennis (1985) described it as a "form of rational thought, reflexive, focused on deciding what it should believe or do". Problem-solving skills is intrinsically related with critical thinking skills, and involves scientific, social and cultural knowledge. It is defined as the ability to solve authentic and

critical real world problems. Both critical thinking and problem solving are relevant skills that help students making better judgements and solve problems (Partnership For 21 St Century Skills 2009).

Motivation towards projects: Motivation is defined as the « *process that prompts people to take action to attain particular goals* » (Soland, Hamilton, and Stecher 2013). It is generally distinguished between extrinsic and intrinsic motivation, separating the motivation that comes from external sources, from the one that stems from the individual. Research tends to support the need to foster motivation in students in order to guarantee acquisition of core academic content (Soland, Hamilton, and Stecher 2013).

3.3 Control Variables

When assessing the role of ME's methodology in students' critical thinking, social and behavioral skills, it is important to consider a number of variables which influence students' ability and performance in school. If we consider the theory behind the education production function, defined as the "relationship between school and student inputs and a measure of school output" (Bowles 1970), there are three main inputs who influence students' achievement: school inputs, environmental factors and students' initial ability and attainment. Controlling for these factors is especially important considering that the present study used a matching procedure to compare a control vs a treatment group of the sample, to possibly uncover a causal relationship between the outcome variables and ME's implementation of PBL. It was not possible to collect all the necessary data from the sample to control for the different factors that influence students' attainment. Particularly, due to logistical and confidentiality reasons, it was impossible to collect data on Nonetheless, it was possible to collect some information which served as control variables, namely:

1) Student characteristics: 1.1 Age: Students' age is an important factor, since it influences students' cognitive development and implies different years in schooling. It is intrinsically related

with students' stages of cognitive development and maturity, which is an important factor in their performance in school. (W. G. Huitt et al. 2009); 1.2 Gender; 1.3 Prior achievement: an important factor to take into consideration when assessing returns of education, is related with students' prior ability and achievement. Since it was not possible to conduct any pretests on students' ability (like IQ tests), two main variables were collected to control for students' prior achievement: retention cases (and number of retentions) and prior grades in Portuguese and Mathematics – two main courses in the Portuguese curriculum.

2) Environmental factors: 2.1 Socioeconomic status (SES): this is considered a crucial factor of home context variables which influence students' performance in school. It is not directly related to school learning but it is crucial as control parameter to assess an educational policy impact (W. G. Huitt et al. 2009). Moreover, in Portugal, a recent study by the Ministry of Education concluded that parent's educational attainment has a significant impact on student's performance in school. Particularly, the study concluded that student's whose mother educational attainment is equivalent to the 3rd cycle of education have a 31% success rate in school, while for student's whose mother has a secondary degree or a higher education diploma, that success rate is equal to 44% and 71%, respectively (Estatísticas da Educação e Ciência 2016). Since it was not possible to collect data on parents' educational attainment or income, the SES measure collected in the present study was *SAS – Serviço de Acção Social* Indicator, which indicates if a certain student has state welfare (like free lunch – or a discount – or free materials like books, etc).

3) School inputs: 3.1 Educational Track: this is an important factor that influences the impact and returns of an educational program, since it implies different methods of teaching and classroom management. Particularly, there were three main educational tracks considered: regular, vocational and professional; 3.2 ME's fellow: the role of the teacher is a crucial variable for students'

performance in school (W. Huitt 2007). It was not possible to guarantee that the treatment and control groups had the same professor in the main courses, however, all students had the same ME fellow – Marta Correia – meaning they all were exposed to the same method of implementing PBL.

4) ME exposure: it was also asked if the students had been exposed before to ME's methodology and program. Considering that educational returns tend to be cumulative, a multiple exposure to ME's methodology (treatment) might have an impact on the outcome.

3.4 Statistical analysis

A statistical analysis was conducted to try to uncover possible statistically significant differences between treatment and control group's outcome in the main variables. The fact that ME is implemented in schools that choose to have the project, and where students chose (or are selected by professors) to be a part of the project, made it impossible to conduct a randomized sample study, which tends to be the easiest way to assess causal inference in social experiments. Instead the present study proposes a quasi-experimental approach, using a matching methodology, where the treatment group is compared to the best possible control group available. The main goal was to estimate the average treatment effect (ATE) and assess if there were any statistically significant differences between the test scores of students who were under ME's project, and those who were not involved.

3.4.1 Causal Inference

In a quasi-experimental design causal inference is defined as a "*comparison of potential outcomes"* where "*the causal effect for individual I is the comparison of individual I's outcome if individual I receives the treatment (the potential outcome under treatment), Yi(1) and individual I's outcome if individual I receives the control (the potential outcome under control), Yi(0)."*(E. A. Stuart 2010). However, and contrary to what happens in a randomized experiment, it is not possible to guarantee

that all unobserved selection problems are avoided. Hence, assessing causal inference becomes a difficult task, where it is necessary to use methods that generate the best possible balance of covariates between the treatment and control groups. One of the main methodological tools used in quasi-experimental designs are matching procedures, defined as "*any method that aims to equate (or "balance") the distribution of covariates in the treated and control groups"* (E. A. Stuart 2010) where there is a "*strategic subsampling from among treated and control cases (…) based on characteristics in Xi (control variables).*"(Morgan and Harding 2006).

The assumptions for the matching procedure to be used were taken into consideration, namely the assumption of strongly ignorable treatment assignment, which implies that the treatment assignment is independent of the outcome, given all covariates and also that there is an existent region of common support – or what is commonly seen as a sufficient overlap in the propensity scores. However, it is worth noting that for the present study, the first part of the assumption above mentioned will be very hard to keep, since the assignment of the treatment – participating on ME's project – was subjected to a different assignment mechanism. Depending on the school a different assignment mechanism was attributed, which at times was not independent from the potential outcome. The second assumption is commonly called SUTVA – Stable Unit Treatment Value Assignment, which means that there is only one possible version of treatment for each unit of the study. Basically, SUTVA implies no spillover effects. However, authors such as Hong and Raudenbush (2006) have argued the need to relax SUTVA for studies involving school effects (E. a. Stuart and Rubin 2008).

3.4.2 Sample and matching process

The sample of students under analysis in this study was pooled from four different schools: Escola Profissional Bento Jesus Caraça, Escola Professor Reynaldo dos Santos, Escola Secundária Daniel

Sampaio e Escola Secundária de Santo André[3]. A total of 113 students participated in the study – 73 in the treated group and 40 in the control group. The sample of 113 students is composed of 63 men and 50 women. It is worth noting that the majority of the individuals' age ranges between 17 and 19 years old. Another interesting factor is the distribution in terms of educational track. 56% of the sample are students from the professional track, while the remaining 44% belong to the regular one. Lastly, it is important to consider the socioeconomic factors and the prior attainment indicators used in the present study. In the sample under analysis, 27% of students have SAS (*serviço de acção social*). Moreover, approximately 43% of students had a negative score in Mathematics, whereas only 21% of the individuals had a grade lower than 3 in the Portuguese exam. Lastly, 21% and 25% of the population had a grade higher or equal than 4 in the Mathematics and Portuguese exam, respectively. To assess which individuals should be matched, it was necessary to conduct several matching procedures and assess the resulting balance in the covariates[4]. The method of choice was the nearest neighbor matching with caliper 0.25[5], considering only the individuals that fall into the region of common support[6]. Nearest neighbor matching is a method that conducts an algorithm in the sample by going through each treated unit and selecting for it the available control unit with the smallest distance – usually measured through the propensity score. With caliper matching, the algorithm choses pairs that fall within a specific distance range – called caliper (E. a. Stuart and Rubin 2008). This ensures that there is not poorly

[3] The four schools were chosen considering both the fact that they were close to Lisbon, but also that all of them were assigned the same Fellow from ME – Marta Correia – ensuring it was easier to implement the framework and reducing bias stemming from how ME's methodology was transmitted to students.

[4] The matching processes tested were: Exact matching, full matching, nearest neighbor matching and nearest neighbor matching with caliper 0.25. A pros and cons list as well as the results of each test are available on Appendix VI, particularly VI.I, VI.II.

[5] Caliper 0.25 was chosen, since most scholars consider it to be a caliper value that works very well in general, guaranteeing a good balance in the covariates, decreased bias and ensuring good matches. (E. a. Stuart and Rubin 2008)

[6] The region of common support ensures that there is a sufficient overlap in the propensity scores of the population that is going to be matched. Therefore, by defining the region of common support, some individuals are discarded before conducting the matching process. In the present study 43 individuals were discarded – 41 treatment and 1 control.

matched pairs – although it also increases the probability that more treated units will not be matched.

A total of 28 pairs were matched – meaning 56 individuals in total were analysed (out of the pool of 113 students). 4 treated and 11 control were unmatched, while 41 treated ad 1 control were discarded. Table 1 provides a summary of the outcome of the matching procedure, namely the balance obtained in each covariate – which can be assessed by comparing the means of the control and treated groups for each covariate (Educational Track, gender, Age, Failed, Socioeconomic (SAS), PORT grades, MAT grades and Participation on ME). Table 4 presents the same summary, but for all data, available on Appendix VI.III. Figures 1 and 2 are a visual representation of the matching outcome, where it is possible to see how the distribution of covariates (measured by the propensity score) is similar between the control and treatment groups.

	Means Treated	Means Control	SD Control	Mean Diff
Distance	0.5091	0.5076	0.0908	0.0015
E. Track	0.7143	0.5000	0.5092	0.2143
Sex	0.3214	0.3571	0.4880	-0.0357
Age	17.5000	17.3626	1.1602	0.1374
Failed	0.2857	0.3929	0.4973	-0.1071
Socioeconomic	0.2143	0.2598	0.4382	-0.0455
Port Grades	3.2497	3.1425	0.6507	0.1071
Math Grades	2.9924	2.7067	0.9744	0.2857
ME	0.0000	0.0061	0.0321	-0.0061

Table 1. Summary of covariates' balance in the matched sample

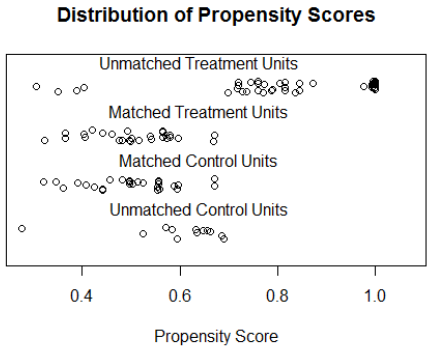

Figure 1. Distribution of propensity scores

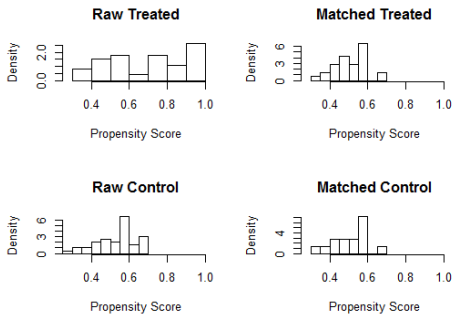

Figure 2. Histogram representing the distribution of propensity scores in the matched sample

3.4.3 Results

To analyse the results and assess the possible impact of a PBL program in students' motivation and critical thinking, the average treatment effect was estimated for pre and post-test conditions. The analysis was conducted only on the matched sample, to allow the comparison of treatment effects and hence the possible drawing of conclusions about this specific implementation of PBL. The average treatment effect (ATE) is defined as the difference between an individual's outcome under treatment and when not subjected to treatment (control).

$$\boldsymbol{ATE = Y_i(1) - Y_i(0)} \qquad \text{Equation 1: Average Treatment Effect (ATE)}$$

Since the matching conducted does not involve sub classification, weighting or replacement it is possible to proceed to the outcome analysis by using the matched samples and estimating treatment effects as if it was a randomized study environment (E. A. Stuart 2010).

Therefore, to analyse the outcome of the critical thinking and motivation tests, it is only necessary to estimate the ATE by conducting the difference in observed means of the treatment and control groups. This is considered to be an unbiased estimate of the average causal treatment effect. Tables 2 and 3 present the means and standard deviations estimates for pre-test and post-test conditions for both the motivation and critical thinking test. It also presents the ATE estimate for post-test conditions for the two tests under analysis.

CT TEST	**Treated**		**Control**	
	Pre-test	Post-test	Pre-test	Post-test
Mean	7.00	8.29	3.75	5.75
SD	5.20	5.83	5.43	4.39
ATE	Post-test		**2.54**	

MT TEST	**Treated**		**Control**	
	Pre-test	Post-test	Pre-test	Post-test
Mean	1.85	1.98	1.82	1.79
SD	0.55	0.71	0.58	0.81
ATE	Post-test		**0.19**	

Tables 2 and 3. Summary of the outcome analysis

Moreover, two independent t-tests were conducted to assess if the ATE estimates of the critical thinking test and the motivation test outcome were different than zero. As presented on table 4, the two ATE estimations are different than zero with a confidence interval of 95. It is also worth noting, that the ATE suggests a positive effect of on both students' motivation and critical thinking.

	C.Interval	Signif. level	t-value	C. value	H0: ATE ≠ 0
CT	95%	0.05	1.84	2.0049	Do not reject
Motivation	95%	0.05	0.78	2.0049	Do not reject

Table 4. Results of the independent t-test conducted on the ATE estimates

Lastly, and in order to better grasp the effect size of the outcome, the effect size estimation, according to Cohen's definition (1988), as well as a difference in differences approach were conducted to assess the differential impact between the treated and the control group.

$$d = \frac{(\mu_1 - \mu_2)}{\sigma} \qquad DID = (\mu_{1_1} - \mu_{1_0}) - (\mu_{0_1} - \mu_{0_0})$$

Equation 2 and 3: Cohen's effect size and Difference in Differences estimation

The results show an effect size of 0.25 for the motivation outcome and 0.49 for the critical thinking outcome. These are considered small and medium effect sizes, respectively. Moreover, when conducting the difference in differences approach, the PBL implementation had a 5.04 increase in critical thinking and 0.16 increase in motivation.

4. Discussion

The treatment effect of the implementation of PBL by *Mentes Empreendedoras*, should be analysed carefully. The ATE for the two outcome variables – the critical thinking test scores and the motivation questionnaire scores – are both positive and statistically significant with a 0.05 significance level. Do these results mean that PBL causes a greater acquisition of critical thinking skills and promotes students' motivation towards projects and school?

Evidence suggests that using this test in this research circumstances may induce a positive bias. Namely in three aspects, most of them common in these type of observational studies. The bias stems from the probable violation of the ignorable treatment assignment, although it is worth noting, that in the matched sample all students were chosen to participate in the project. It is also important to consider the different implementation strategies, since students came from different schools, hence they also had different teachers guiding their PBL experiment. This source of biased

was nonetheless reduced, by guaranteeing that the sample was pooled from schools where the same ME fellow was implementing the project. Lastly, and not less important, is the bias coming from the covariates. As mentioned, great balance was achieved between the matched samples. However, the covariates selected tried to address different factors that influence students' attainment in school. Nonetheless, for reasons of data protection and also logistics, it was not possible to collect all the necessary information (example: individual grades; parents' level of education and income). Therefore, although the matching conducted generated a good balance, it does not necessarily mean that the pairs are the most similar. This fact is most likely the cause of the different baseline levels in terms of critical thinking skills in the treatment and control groups.

Besides the quantitative aspects, it was also possible to gather the testimonies of both teachers and students. Through their opinions it was possible to better understand the effect of PBL, and also to confirm the results obtained. A student from Algarve, which was a part of ME for 3 years stated how *"ME's activities tend to stimulate critical thinking skills, since it implies the analysis of different options to solve a project or situation within a project."* A teacher from Vila Franca de Xira, also mentioned how it felt the project was beneficial, since it makes students be "*more proactive and more willing to do things, achieve goals and acquire new skills to reach their objectives*". The same teacher also mentioned how the project promotes the opening of the school to the community, which allows synergies and opportunities for both parties. Therefore, when combining the quantitative findings, with the qualitative information, evidence suggests a positive effect of the PBL implementation on students' motivation and critical thinking. Moreover, this was even more obvious when looking to the first critical tests where students were incapable of distinguishing reason from an opinion, a valid argument from a personal point a view. This was a symptomatic issue, since the great majority of students showed the same exact issues. However,

after being subject to only 3 months of PBL, students' tended to show improvement on these topics, which indicates a progress in their critical thinking skills.

5. Conclusions: Moving forward

The present study's objective was to develop a measure of learning outcomes for soft skills development namely critical thinking and motivation, by using the context of ME to do it. The results provide some info and debate material. The results contribute with the following results to the discussion: PBL seems in fact a valid educational approach to increase/improve students' critical thinking, thought process and get more involved and interested in doing projects and participating in school activities – and even the community. These are a result of the framework implemented, but also of the testimonies of both students and teachers on how ME's project improved their school experience and their skills. Still, moving forward better results in terms of assessing reasoning and behavioral skills can be obtained if a richer set of data is available to the researcher – namely what concerns students' unobservable factors, such as parent's income and their educational attainment information. Moreover, some of these issues can also be solved by changing the research design, namely using a randomized method when establishing the treatment and control units. Nonetheless, these results suggest evidences of a positive effect of ME's implementation of PBL on both students' motivation and critical thinking skills.

It was clear that the school burden of many students obstructed their engagement and their available time to spend in developing and implementing a project. It was also clear that ME's methodology's asymmetry - either a voluntary club where students freely choose to join or a teacher chooses to incorporate it in a class - influences the way PBL is implemented but also students' willingness and engagement in the projects. Moreover, the testimonies and results also seemed to favor a

continuous implementation of the project – meaning that students tend to be more engaged when they experience the project for 2 or 3 years in school.

Lastly, a final note. The present study assessment of critical thinking skills showed a symptomatic problem: the vast majority of students under analysis were incapable of distinguishing arguments from personal points of views and emotion. A knowledge-based economy asks people to challenge themselves, to think outside the box, be creative and solve problems quickly. A great part of that is the ability to judge critically and with reason. Moving forward, it would be important to assess how educational programs and approaches, are dealing with these challenges and how we as a society think education should be. Therefore, more research is necessary not only to assess PBL's impact on acquisition of knowledge, but also on its possible effect in reasoning skills.

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